

CONDUCTIVITY-MODULATION METAL OXIDE FIELD EFFECT TRANSISTOR WITH SINGLE GATE STRUCTURE

This application is a continuation-in-part application of the co-pending U.S. patent application Ser. No. 233,425 filed on Aug. 18, 1988 (now abandoned) which is a continuation-in-part of co-pending U.S. patent application Ser. No. 160,277 filed on Feb. 25, 1988, now U.S. Pat. No. 4,980,743.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to metal insulator semiconductor field effect transistors and, more particularly, to an improvement of a conductivity-modulation MOSFET.

2. Description of the related art

A conductivity-modulation MOSFET has a semiconductive drain layer, an N type conductivity base layer (N base region), and a base layer (P base region) of P type conductivity. The P base layer is formed by diffusion in an N type semiconductive layer serving as the N base layer. A heavily-doped N type layer (N⁺ layer) is formed on the P base layer to define a channel region of the MOSFET. A gate electrode layer insulatively covers the N base layer and the channel region, and a source electrode layer electrically shorts the P base layer and the N⁺ source layer. When a positive voltage is applied to the gate electrode, the channel region is inverted, so that carriers (electrons) are injected from the N⁺ source layer into the N base layer. When the electrons enter the drain layer through the N base layer, the PN junction of the MOSFET is forward-biased, and as a result, the MOSFET is turned on. When a zero or negative voltage is applied to the gate electrode, the inverted layer in the channel region disappears, and hence, the channel disappears. As a result the MOSFET is turned off.

In order to improve a turn-off switching speed of such a conductivity-modulation MOSFET, carriers accumulated in the N base layer thereof must disappear faster. However, with a conventional conductivity-modulation MOSFET, if the carrier lifetime in the N base layer is shortened in order to improve the turn-off speed, a voltage in the device becomes undesirably high, which leads to the difficulty in turn-on drive of the MOSFET.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved conductivity-modulation field effect transistor.

It is another object of the present invention is to provide a new and improved conductivity-modulation field effect transistor which can increase a turn-off switching speed while an on-state voltage thereof is kept lowered.

In accordance with the above objects, the present invention is addressed to a specific semiconductor device, which has a semiconductive substrate, and a single-gate type conductivity-modulation field effect transistor formed on the substrate. The transistor has a first base layer, a second base layer, and a source layer formed in the second base layer. A source electrode is provided on a surface of the first base layer, for electrically shorting the second base layer with the source

layer. A drain layer is provided in the first base layer surface. A drain electrode is formed on the layer surface to be in contact with the drain layer. A gate electrode is insulatively provided above the layer surface, for covering the certain surface portion of the second base layer which is positioned between the first base layer and the source layer to define a channel region below the gate electrode. A heavily-doped semiconductor layer is provided in a selected surface portion of the drain layer to have the opposite conductivity type to that of the drain layer. This semiconductor layer is included in the drain layer to be in contact with the drain electrode. The heavily-doped semiconductor layer facilitates, when the transistors is turned off, carriers accumulated in the first base layer to flow into the drain electrode through the drain layer, thereby accelerating dispersion of the carriers in said transistor, so that the aforementioned objects can be attained.

The invention, and its objects and advantages, will become more apparent in the detailed description of preferred embodiments presented below.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description of a preferred embodiment of the invention presented below, reference is made to the accompanying drawings of which:

FIG. 1 is a diagram showing a basic cross-sectional structure of a conductivity-modulation MOSFET of single gate type;

FIG. 2 is a diagram showing a cross-sectional structure of another conductivity-modulation MOSFET of single gate type;

FIG. 3 is a diagram showing a sectional structure of a main part of a conductivity-modulation MOSFET of single gate type according to a preferred embodiment of the present invention;

FIG. 4 is a diagram showing a sectional structure of a main part of a conductivity-modulation MOSFET of single gate type which is a modification of the MOSFET shown in FIG. 3;

FIG. 5 is a diagram showing a sectional structure of a main part of a conductivity-modulation MOSFET according to a second embodiment of the present invention;

FIG. 6 is a diagram showing a plan view of a main part of a conductivity-modulation MOSFET in accordance with a third embodiment of this invention;

FIGS. 7 and 8 are diagrams showing sectional structures taken along different cutting lines of the MOSFET of FIG. 6;

FIG. 9 is a diagram showing a plan view of a main part of a conductivity-modulation MOSFET in accordance with a fourth embodiment of this invention;

FIGS. 10 and 11 are diagrams showing sectional structures taken along different cutting lines of the MOSFET of FIG. 9;

FIG. 12 is a diagram showing a sectional structure of a main part of a fifth embodiment of this invention;

FIG. 13 is a diagram showing a sectional structure of a main part of a modification of the embodiment shown in FIG. 5; and

FIG. 14 is a diagram showing a sectional structure of a main part of another modification of the embodiment shown in FIG. 5;

FIG. 15 is a diagram showing a sectional structure of a modification of MOSFET shown in FIG. 14;

FIG. 16 is a diagram showing a sectional structure of a modification of MOSFET shown in FIG. 3;